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The changing role of innovation for crisis management in times of COVID-19: An integrative literature review

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ABSTRACT

Since the outbreak of the COVID-19 pandemic, countries have concentrated on developing policies that encourage the creation of more innovative products and services in response to the global health emergency. Effective collaboration, communication, and Open Innovation (OI) among government entities, education and research institutions, and the private sector have been critical to each country's overall effectiveness during the economic crisis. The objective of this paper is to examine the relationship between innovation and COVID-19 critically to have a better understanding of future research and practice developments. A systematic evaluation was conducted, analyzing papers on innovation and the COVID-19 pandemic. A total of 218 studies were analyzed to determine the essential research directions in this domain. Our suggested framework is made of aggregate components, which include technology adaption, sustainable development, healthcare, and sustainable economic performance. These components form the basis for the identification of emerging research hotspots in the field of COVID and innovation, as well as frame the COVID-19 issue as an opportunity to raise awareness about the crucial role of innovation in business and society at large.

Introduction

The ongoing COVID-19 pandemic has had a significant impact on global health and economic development (Meyer, Niemand, Davila & Kraus, 2022). Apart from its direct influence on individual health, it also had an indirect effect on social, economic, and political institutions. COVID-19 has plunged the global economy into the worst slump since the Great Depression. Time restrictions and resource limits require redoubling efforts to conceptualize, create, and implement new ideas, goods, and services with an innovative mindset. On the other hand, the pandemic has also provided opportunities for future growth and the development of more robust and humanitarian responses in the case of similar future catastrophes. Innovations in the fields of health, pharmaceuticals, energy, artificial intelligence, and quantum computing (Soumitra, Bruno, Rivera León & Wunsch-Vincent, 2021) are critical to overcoming such roadblocks. Digital methods and technical advancements are gaining traction as a global phenomenon in the fields of work, living, learning, and recreation. Bessonova and Battalov (2021) opine that digitalization is steering the strategic development of the global economy. Digital technologies accelerate economic progress driven by innovation by enabling the flow of ideas and data (Wendt, Adam, Benlian & Kraus, 2021). Governments are boosting their investment in innovation in response to the COVID-19 pandemic, to assist humankind in navigating the crisis by raising scientific output, extending research and development, and filling patents (Guderian, Bican, Riar & Chattopadhyay, 2021; Soumitra et al., 2021). Recent advances, fueled by technological revolutions (e.g., Industry 4.0), economic crises, and new regulations, create new opportunities for manufacturing materials, structures, processes, and capacities. Innovative technologies improve business analysis and forecasting, new product creation, order processing, logistics, factory automation, quality control, and marketing (Jemala, 2021). Wang, Zhang and Verousis (2021) examine the effect of the duration of the pandemic on innovation output and suggest that policies directing innovative firms are on the right path and their recovery time is reduced. Business model innovation (BMI) can assist SMEs in remaining competitive during crises while

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focusing on revenue creation and value addition (Adam & Alarifi, 2021; Clauss, Breier, Kraus, Durst & Mahto, 2022; Ibarra, Bigdeli, Igartua & Ganzarain, 2020). Open innovation activities (interaction with consumers and open exchange of knowledge about market demands and technological possibilities) can be beneficial in minimizing the impact of COVID-19 on education, the economy, and leisure (Almeida, 2021; Surya et al., 2021). Several organizations have restructured their innovation and manufacturing services to assist health and associated services in meeting supply shortages during emergencies such as COVID-19. This is accomplished most effectively through the use of a dynamic capabilities viewpoint centered on meeting societal expectations rather than chasing competitive advantage in a crisis scenario (Puliga & Ponta, 2022). In the future, innovation gaps will be obvious and noticeable across diverse industries and economies. Thus, innovation ecosystems need to be improved to bridge the imbalance across sectors (such as ICT, pharmaceuticals, R &D, hospitality, or automobiles) with the help of investments in new technology and business strategies.

In the past two years, various studies have focused on innovation as a state-of-the-art strategy for surviving situations like the COVID-19 pandemic, highlighting innovation's crucial importance (e.g., Sharma, Lopes de Sousa Jabbour, Jain & Shishodia, 2022). By synthesizing the knowledge generated by this scholarship, one can accomplish two critical goals: draw policy lessons for enhancing innovation in response to situations like the COVID-19 pandemic, and set the stage for future scholarship that will advance knowledge in various domains of innovation. We conducted this study to address these dual research goals and gain a better understanding of what these new technologies may provide in a rapidly changing world. We conduct the review of available literature in the field scientifically and systematically (e.g. Kraus et al., 2022).

The COVID-19 outbreak has wreaked devastation on healthcare facilities and treatment systems almost all over the world (García-Carbonell, Martín-Alcázar & Sánchez-Gardey, 2021). Moreover, due to the COVID-19 pandemic, especially SMEs, face a variety of issues and hurdles (e.g., Emami, Ashourizadeh, Sheikhi & Rexhepi, 2021). The time of closure and movement prevention measures enacted by governments in numerous nations have severely impacted SME operations, weakened their financial standing, and exposed them to financial risk (Omar, Ishak & Jusoh, 2020). Consequently, numerous organizations were unable to deal with the problem (Ozili, 2020). Some firms have ceased operations and stayed closed since the outbreak's earliest months. Insufficient research has also been conducted on the influence of external support obtained by SMEs after the COVID-19 epidemic on their performance and survival (except for Song, Yang & Tao, 2020). In response to the problems provided by COVID-19, the purpose of this study is to undertake a literature assessment on the efficacy of innovation approaches employed by diverse organizations. In the case of a pandemic, organizations must adapt to new technology and financial applications.

New policies are required immediately to boost economic resilience and sustain long-term growth. Contributing to the establishment of an economic recovery strategy is critical in this respect. Entrepreneurship is critical for the prosperity and well-being of society. Globally competitive, the green economy is also ecologically and socially sustainable. Additionally, the role of innovation and initiatives is critical in the post-COVID-19 period. As a consequence, we present fresh insights into how to nurture innovation processes and R &D units in the real world through this study, to accomplish SDG 9.

The study conducts an integrative review for consolidation and critical evaluation of theoretical contributions and development of the subject in an integrated manner with a scientific, transparent, and reproducible approach to deepen our understanding of innovation for crisis management during COVID-19 (Bouncken, Kraus & de Lucas Ancillo, 2022). We summarize the existing literature on the topic by using a bibliometric approach using R (Aria & Cuccurullo, 2017). A bibliometric review is a form of theme-based review that emphasizes statistics and trends related to a review topic. Bibliometric analysis is a useful technique for evaluating and analyzing the findings of academic research. It aids in analyzing progress, locating the most trustworthy sources of scientific literature, creating academic frameworks for judging discoveries, establishing bibliometric indices to measure academic production, and identifying major scientific actors (Akpan, Udoh & Adebisi, 2022; Mahendru, Sharma, Pereira, Gupta & Mundi, 2022). Ultimately, we also offer a framework composed of first-order concepts, second-order themes, and aggregate dimensions (see Fig. 4). Our proposed framework includes technological adaptability, sustainable development, healthcare, and sustainable economic performance. These parts of the data structure are used to suggest new hotspots for research in the fields of crisis management and innovation.

Data and methods

The COVID-19 crisis has caused immense disruption in lives and livelihoods across the globe, but human ingenuity and resilience have endured in the form of innovation to overcome the pandemic-related crisis. We conducted this review to embrace innovation through the creation and augmentation of infrastructure in the areas of health, education, trade, and industry. Research articles in the past have been less recognized and have been inconsistent in addressing innovation during the COVID-19 pandemic (Araújo, 2022; Boeing & Wang, 2021; Mota Veiga, Fernandes & Ambrósio, 2022; Rocha, Pirson & Suddaby, 2021). Governments worldwide have utilized innovation to combat pandemics through the diffusion of relevant technology, enhancement of medical infrastructure, and a large number of additional types of policy interventions. We use bibliometric analysis to analyze the current state of the subject matter and build a research-driven policy agenda, followed by a manual review of each sample article.

We have used an advanced search in the Scopus database by using keywords related to COVID and innovation. Scopus is a widely acknowledged database as it provides the most extensive overview of the world's research output in the streams of science, technology, social science, humanities, and arts. The Scopus database is equipped with numerous functions that facilitate bibliometric analysis, which include the journal title, number of citations, type of document, authors, as well as authors' affiliations, year of publication, and h-index metrics. In sum, Scopus contains 21,000 journal titles and its wide feature coverage facilitates faster viewing of orphaned and errant records (Agarwal et al., 2016).

We filter the papers to retain only the journal articles in English related to the fields of "Business, Management and Accounting" and "Economics, Econometrics and Finance", which leaves us with 1255 papers (see Fig. 1 for details). These 1255 papers are categorized on account of the ABS list, and we review the papers published in ABS 2 and above-ranked journals, bringing the number of finally selected papers to 218. We use the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines for conducting and reporting research articles in Fig. 1 (Moher, Liberati, Tetzlaff & Altman, 2009). While performing an integrative review, the PRISMA flow diagram helps to demonstrate the various search efforts that are carried out throughout the review's lifetime and the choices made during the inclusion and exclusion of the articles to be selected for the review (Stovold, Beecher, Foxlee & Noel-Storr, 2014).

The use of quantitative approaches (i.e., bibliometric analysis—e.g., citation analysis) to bibliometric data (e.g., units of publication and citation) is referred to as *bibliometrics* (Broadus, 1987). Bibliometric analysis is a rigorous and thorough method for discovering and analyzing large volumes of scientific data. It allows us to unpack the evolutionary subtleties of a particular discipline while also offering insight into the budding field of the research area. However, its

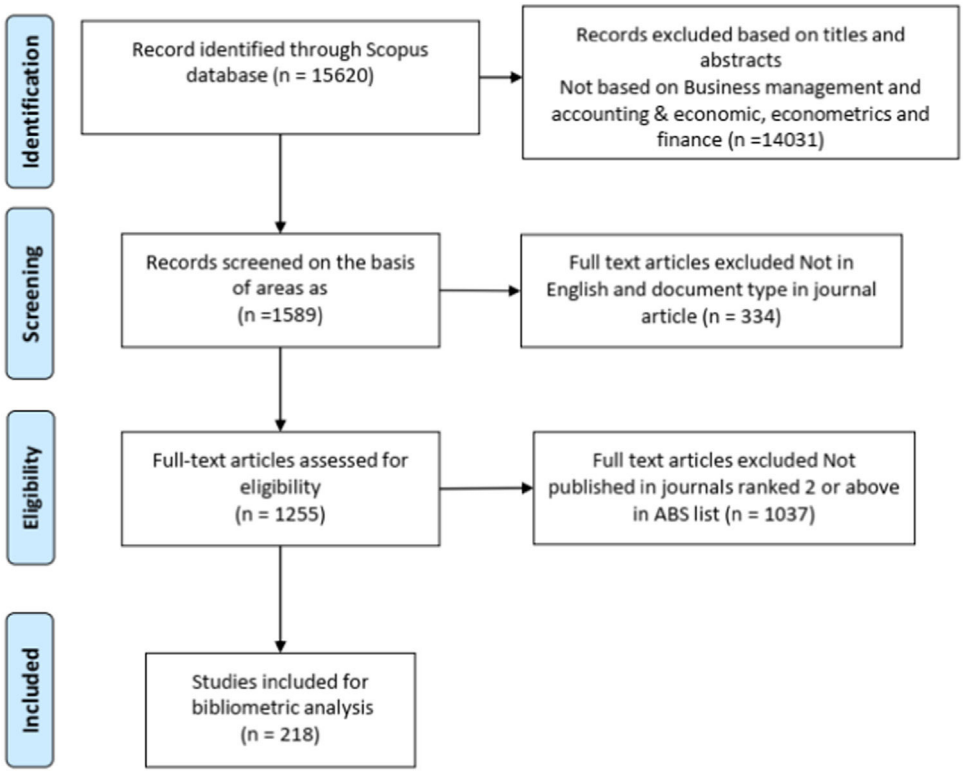

Fig. 1. PRISMA diagram for inclusion of articles.

use in business research is still very young and, in many cases, underdeveloped. Our bibliometric analysis helps uncover the emerging trends of research papers oriented toward COVID-19 and innovation through the use of the Bibliometrix R-tool.

Descriptive and conceptual structures

Thematic map

The prevailing section illustrates the development of the theme "COVID-19 and Innovation" from 2019 to 2021. This longitudinal analysis is used to better understand the expansion of an academic area by identifying the development patterns and internal dynamics of a related discipline. As illustrated in Fig. 2, the analysis demonstrates the evolution of academic domains critical for information transmission and dissemination to interested stakeholders (Waila, Singh & Singh, 2016). The themes in the map are organized according to *Callon's centrality*, which quantifies the degree of interaction between them, and *Callon's density*, which quantifies the internal strength of the themes (Callon, Courtial, Turner & Bauin, 1983). These two measurements are divided into four quadrants on the thematic map within the two-dimensional strategy diagram (Chen, Lun, Yan, Hao & Weng, 2019). The four quadrants portray the following themes: 1. Motor themes that are well-developed in the upper-right quadrant; 2. Niche themes that are marginally significant in the upper-left quadrant; 3. Declining or emerging themes in the lower-left quadrant that are poorly developed; and finally, 4. Basic themes that are significant but undeveloped in the lower-right quadrant.

This thematic evaluation map depicts the analysis of 218 publications in total. The motor theme has a high degree of centrality and density and includes *artificial intelligence, corporate image, social responsibility, digital technologies, e-commerce,* and *tourism*, whereas emerging themes include *economic performance*. Most keywords are observed as basic themes incorporating the *COVID-19 pandemic, dynamic capabilities, innovation, performance, digital health, telemedicine, SDG, and sustainability*.

Artificial intelligence (AI) is a critical theme in the fight against COVID-19 and may accelerate the development of solutions in a variety of disciplines and applications. Since the pandemic's breakout, there has been a rise in the development and usage of artificial intelligence and other data analytic technologies in a wide variety of fields such as supply chain management (Dilyard, Zhao & You, 2021), healthcare systems (S. M. Lee & Lee, 2021), predicting any virus outbreak (Chamola, Hassija, Gupta & Guizani, 2020), etc. Additionally, Chamola et al. (2020) examined how technologies such as the Internet of Things (IoT), Unmanned Aerial Vehicles (UAVs), blockchain, Artificial Intelligence (AI), and 5 G can assist in lessening the impact of the COVID-19 outbreak. As per Jo Hatch and Schultz (2003), *corporate images* are distinct perspectives on an organization produced by the company's various stakeholders, including customers, the media, and the general public. Henna (2022) explains how sustainability might provide customers with charitable value. Additionally, it can have an impact on the corporate image via sustainable business model developments. This can occur as a result of businesses not intentionally utilizing sustainable business model innovations in managing their corporate image or as a result of businesses utilizing sustainable business model innovations in other areas, such as social media marketing. In previous literature, *social responsibility* has been mostly used as corporate social responsibility. Corporate social responsibility has been recognized as a worthwhile strategic initiative for firms. Previous research has established the benefits of corporate social responsibility activities. According to Puriwat and Tripopsakul (2021), social responsibility may help businesses improve their financial performance, brand image, and brand loyalty, as well as job seekers' impressions of companies and clients, and purchase intentions. Any social responsibility activities conducted on digital networks might be considered digital social responsibility (DSR). There has been a paradigm shift away from brick-and-mortar businesses toward brick-and-click ones (Zhang & Wang, 2022). CSR

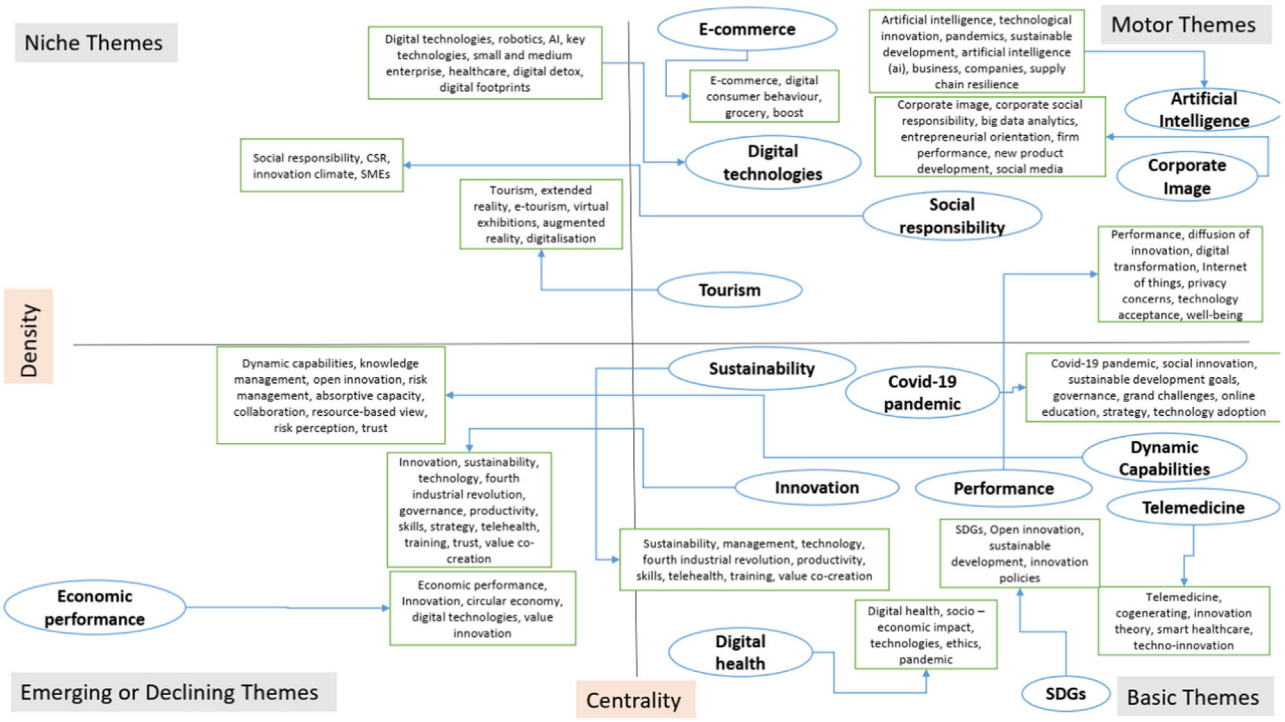

Fig. 2. Thematic map.

operations that are currently conducted on a paper basis must be transformed into digital ones. The pandemic of COVID-19 is one of the most serious and unanticipated causes, igniting and compelling organizations to adapt digitally (G. D. G. D. Sharma, Talan & Jain, 2020; Tworzydło, Gawroński, Opolska-Bielańska & Lach, 2022). Furthermore, four interrelated *digital technologies* (the Internet of Things, big data analytics, artificial intelligence, and blockchain) have been discussed in the context of enhancing two traditional public-health strategies for addressing COVID-19: monitoring, surveillance, detection, and prevention of COVID-19; and mitigating the impact of COVID-19 on healthcare indirectly (Zhao et al., 2021). *E-commerce* has been demonstrated to be one of the most effective strategies for resuming activities during the COVID-19 epidemic (Hoang, Nguyen & Nguyen, 2021). To decrease infection, it is necessary to prevent human-to-human transmission and to increase the virtual platform established by technology. Sellers can continue to find buyers online and provide services with the assistance of specialized logistics (Nuru, 2020). The new e-commerce standards build on classic marketing theories by including an understanding of digital consumer behavioral traits, collecting customer feedback, and generating value propositions that provide consumers with a higher degree of satisfaction. Consumer behavior and purchasing patterns dramatically changed during the COVID-19 crisis (Bartoli, Bonetti & Mattiacci, 2021; G. D. G. D. Sharma et al., 2020). *Tourism* (Dileep & Nair, 2021) has been linked to increased environmental deterioration as a result of foreigners visiting the host country (Sun, Duru, Razzaq & Dinca, 2021), with ecological innovation emerging as a potential solution for reducing carbon emissions. By contrast, researchers (Price, Wilkinson & Coles, 2022; Vu & Hartley, 2022) agree on the beneficial association. Digitalization is an illustrative example, ranging from online and mobile hotel reservations, airline tickets, and restaurant reservations to personalized travel package services. There is a global trend toward consumer-driven and ecologically friendly innovations in tourism and hospitality that encompass the range of interconnected services and goods packaged into a single quality perception of the destination and local community by a tourist. It is worth noting that both vectors of expanding and contracting research and inventive organizations largely parallel the patterns observed for travel agents and, to a lesser extent, housing facilities, sanatoriums, and resorts (Gorochnaya, Mikhaylov, Plotnikova & Mikhaylova, 2021).

Economic performance is one of the key factors directly affected by the COVID-19 pandemic, resulting in reduced worldwide economic growth estimates. The pandemic has a wide-ranging effect on economic activity, ranging from significantly reduced consumer discretionary spending to a freeze on business activities such as capital budgets, recruiting, and all but required operational expenses. Nonetheless, it is evident that certain businesses, such as those in the information and communication technology (ICT) industry, may become more vital to our lives and face increased demand in the current environment (International Telecommunication Union (ITU), 2020).

The COVID-19 pandemic has also appeared to be one of the prominent cluster names, which is a complex catastrophe that has wreaked havoc on communities worldwide. It is a crisis for a variety of entities, including individuals, organizations, and entire societies, because it jeopardizes their survival and objectives. Additionally, the utilization of IoT, Unmanned aerial vehicles (UAVs), robotics, smart wearables, artificial intelligence (AI), blockchain, and 5 G technologies to successfully manage the outbreak has been extensively investigated (Chamola et al., 2020). Furthermore, social innovation has become prevalent in pandemic times, which can be defined as "the use of novel, practical, sustainable, market-based ways to benefit society as a whole, and the low-income or underserved community in particular." COVID-19 has disproportionately impacted vulnerable groups that are already marginalized due to their gender, color, or nationality. Social innovations have been developed in response to protect vulnerable groups and rapidly transition health systems to COVID-19. Social innovations in health are inclusive solutions that overcome the healthcare delivery gap by addressing the requirements of end-users through a multi-stakeholder, community-engaged process. Social innovation is ideally suited for the COVID-19 response because it focuses on local needs, provides low-cost solutions, and leverages community assets. *Dynamic capabilities* emerged as a basic theme

and are defined as the capability of an organization to purposefully adapt an organization's resource base, in terms of organizational theory (Shrestha & L'Espoir Decosta, 2021). Volatility, uncertainty, complexity, and ambiguity are increasing in today's environment, emphasizing the critical nature of firms' ability to adapt to changing market conditions in order to sustain their innovation initiatives (Schoemaker, Heaton & Teece, 2018). The dynamic capabilities view (Teece, Pisano & Shuen, 2009) provides a theoretical foundation for understanding the capabilities required for innovation by theorizing how to respond to such changing market conditions through the integration, development, and reconfiguration of organizational competencies. *Innovation* appeared as a prominent theme since it is directly related to the topic of study. It has been demonstrated earlier that the majority of innovations occur as a result of discrete events and new technology opportunities (Corsini, Dammicco & Moultrie, 2021). Innovation is defined in this context as a creative response that necessitates the commitment of resources to the development of new products or processes. The coronavirus disease pandemic of 2019 can be believed to be a distinct event that resulted in known innovation-inducing factors such as profit losses, increased demand for specialized products, and supply chain disruptions (Nasser, 2021). This pandemic also happened during a period of technical opportunity, as a result of ongoing research in domains such as advanced manufacturing, robotics, and digital technologies, as well as the beginning of their implementation in numerous sectors of society (Zimmerling & Chen, 2021). *Performance* has been largely used as organizational, firm or business performance in the extant literature. The pandemic served as a reminder to business leaders of the critical nature of expanding firm performance metrics to include resilience, responsiveness, and configurability (Syriopoulos, Tsatsaronis & Gorila, 2020). The *digital health* theme emphasizes the latest technologies in digital healthcare technologies. Even prior to the COVID-19 problem, the worldwide smart wearable healthcare (SWH) market was predicted to grow at a compound annual growth rate of more than 5.6 percent, reaching $25 billion in 2020 (Papa, Mital, Pisano & Del Giudice, 2020). The increasing necessity for detection and monitoring during the crisis has boosted their use; for example, Hong Kong authorities compel foreign visitors to wear monitoring bands to ensure they adhere to a two-week quarantine (Brem, Viardot & Nylund, 2021). The bracelets are embedded with a QR code that must be scanned using a smartphone application. The strength of communications signals such as Wi-Fi or Bluetooth assists in determining whether or not the wearer is adhering to self-isolation requirements (Brem et al., 2021).

Telemedicine has become prevalent in pandemic times. Telemedicine, or telehealth, is a broad term that relates to the electronic transmission of medical data from one location to another. It makes use of technology to provide clinical health care to patients remotely. In recent years, regulators have taken significant steps, such as eliminating numerous prohibitions, to aid in the promotion of telemedicine (Gopalakrishnan & Kovoor-Misra, 2021). From popular fitness bracelets to booming remote heart rate or respiratory monitors, telemedicine technologies have grown in popularity. By frequently combining off-the-shelf hardware with specialized software, the gadgets continue to shrink in size while increasing their feature set. On the soft infrastructure side, startups such as Nurx and Omada Health (Condry & Quan, 2021) have developed platforms and programs that deliver the benefits of telemedicine to patients ranging from diabetics to women in rural areas in need of birth control pills. The marriage of hardware and software has significantly advanced home-based care that requires precise remote monitoring.

SDG has been the most talked about theme in the extant literature in almost all disciplines. According to the United Nations' (UN) Sustainable Development Goals Report, the pandemic halted progress on all 17 Sustainable Development Goals (SDGs), which had already begun to regress slightly prior to the onset of COVID-19 (UN, 2021). Citing the 2030 Agenda for Sustainable Development, the report asserts that these hardships necessitate immediate but bold action by "... governments, parliaments, the UN system and other international institutions, local governments, civil society, business and the private sector, the scientific and academic community—and all people to reignite the SDGs and demonstrate our indisputable commitment to promoting economic growth with equity and social inclusion" (UN, 2018). *Sustainability* has emerged as a critical theme in the said area as COVID-19′s severe consequences have created unprecedented issues that are affecting markets, governments' policies, consumer preferences, and technical advancements worldwide (Acioli, Scavarda & Reis, 2021). In light of these problems, we may rediscover the urgency of addressing global climate change by focusing on new actors whose innovative ideas might pave the way for the creation of sustainable societies with greater standards of living for all inhabitants. As a result of the epidemic, global communities and economies have had an opportunity to think about the various areas in which creative solutions could result in long-term sustainability improvements. However, the fact is that the long-term sustainability of multinational firms' social innovation business models is difficult to establish, and success is contingent on several criteria (Falorca, 2020). This includes the trifecta of sustainable and innovative government policies that favor and incentivize multinational enterprises to create social value through business model innovation; socially innovative and environmentally conscious managers, investors, and shareholders; and international organizations that guide, assist, or aid countries in developing their strategic initiatives and providing roadmaps for their enterprises to create social value (Acioli et al., 2021).

Keyword analysis map

The keyword analysis indicates the themes that have happened more frequently in each cluster, indicating the field's current hot topics, as Wang, Pan, Ke, Wang and Wei (2014) assert, in this case, "COVID-19 and Innovation." According to Zupic and Čater (2015), keywords are believed to reflect knowledge domain themes, and their presence in a document suggests linkages between document topics (Bamel, Pereira, Del Giudice & Temouri, 2020, p. 13). The keywords were collated using the Bibliometrix R-tool program; 50 keywords were created and classified into four groups, respectively, from 213 research articles. The purpose of clustering topics is to assist readers in becoming acquainted with the subject/theme being researched (Delecroix & Epstein, 2004).

Each article includes a minimum of 4–6 author-specific keywords that aid in describing the content of papers. Their co-occurrence indicates how a field of study has evolved and developed through time. The larger the nodes, the more frequent the occurrence; the lines connecting these nodes show co-occurrence (see Fig. 3). The most frequently used keywords were "COVID-19″, "innovation", "entrepreneurship", "technological innovation" and "social innovation", which have the highest occurrences, pointing to research emphasizing the importance of innovation and entrepreneurship during the pandemic. The color coding was used to differentiate the various clusters depicted on the map (van Nunen, Li, Reniers & Ponnet, 2018). The keyword network analysis map depicts six distinct clusters (arranged in decreasing order of keyword count): Cluster 1 (red, 19 keywords), cluster 2 (blue, 5 keywords), cluster 3 (purple, 2 keywords) and cluster 4 (green, 2 keywords). COVID-19, from cluster 1, ranks first in terms of total occurrences (59).

Fig. 4 presents the data structure of concepts, themes, and aggregate dimensions, created using both bibliometric and manual analysis of sample studies. Concepts are framed using the subthemes and author keywords derived from the thematic map and sample studies, respectively. The themes are derived using the cluster name of the thematic map and the most co-occurred keywords from the keyword

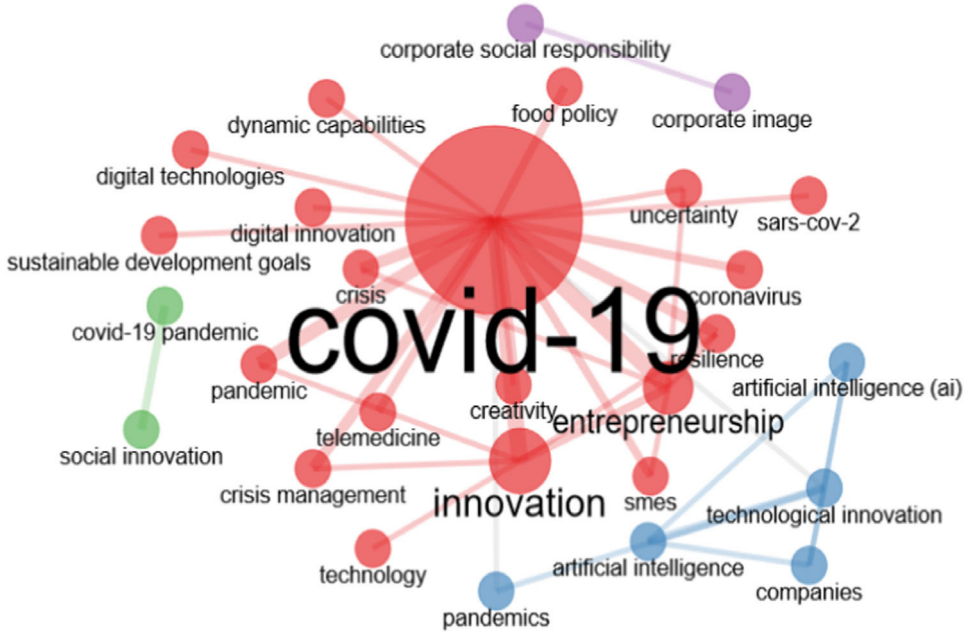

Fig. 3. Keyword co-occurrence analysis map.

analysis co-occurrence map. Lastly, the aggregate dimensions are produced by combing various second-order cluster themes.

Technological adaptation comprises three themes: e-commerce, digital technology, and artificial intelligence. E-commerce contributes to the simplification of company procedures and their acceleration and efficiency. Organizations benefit from increased productivity as a result of e-commerce. It enables supply chain management on a pull basis. In pull supply management, a business process begins when a customer makes a request and employs a just-in-time manufacturing method (Nuru, 2020). Digital technologies (Sharma et al., 2022) have increased enormously in popularity, and their use has become increasingly global. Due to the widespread use of smartphones and the resulting access to information, social networks, and audiovisua entertainment, widespread and continuous connectedness has reached a large portion of humanity. The pace of technological advancement in the digital arena has made the usage of cloud computing, big data analysis, blockchains, and artificial intelligence devices and applications routine (Álvarez, Natera & Suarez, 2020; El

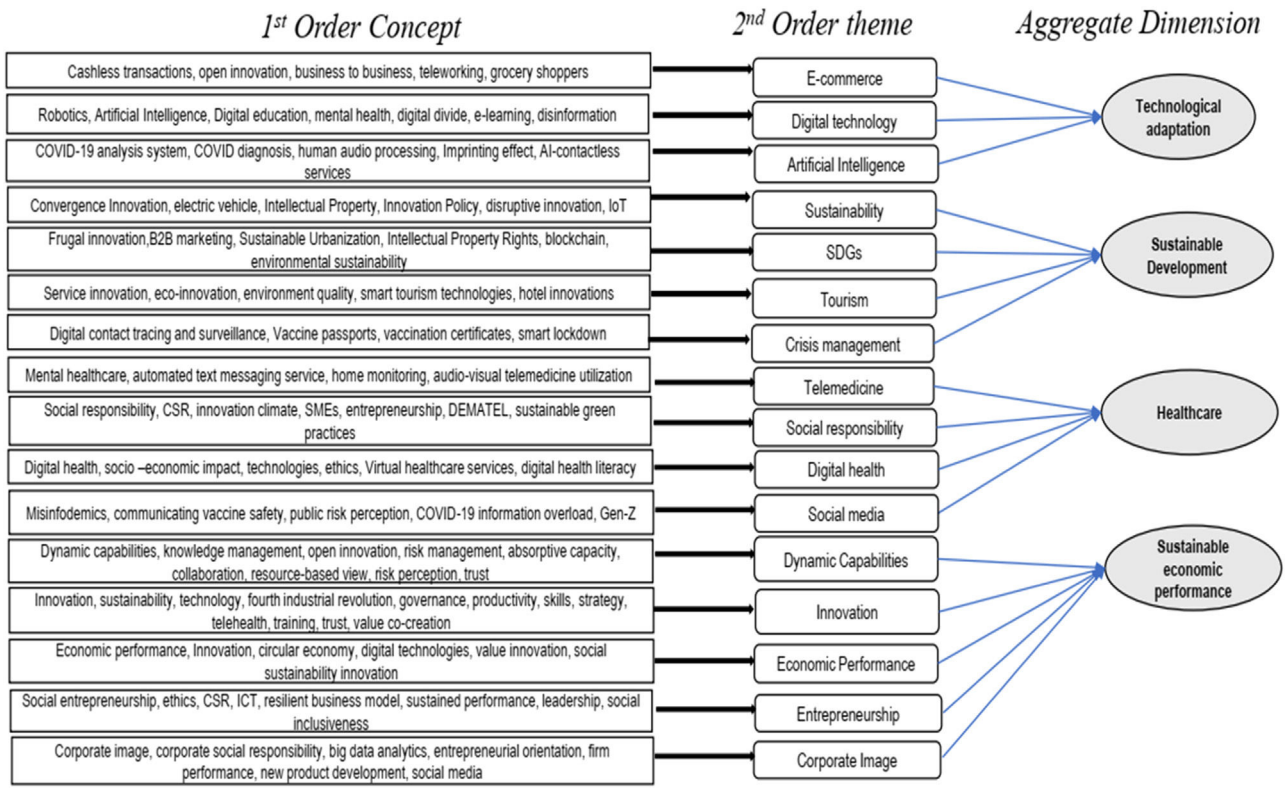

Fig. 4. Concepts, themes and aggregate dimension.

Sayed, 2020). Technological advancement has been accompanied by socially negative consequences, such as the exclusion of a sizable portion of the world's population from the advantages of digitalization, largely because their incomes are insufficient to provide meaningful connectivity (i.e., high-quality access), access to devices, fixed home connections, and the ability to use these on a daily basis (X. Li, Yuen, Wang & Wong, 2021). As a result, a sizable demand gap has developed, as appropriate coverage is not reflected in connections and consumption. Other issues, such as the development of fake news and cyber-attacks, the growing threat to privacy and personal data protection, and the large-scale generation of electronic waste, have also gotten worse (R. Sharma et al., 2022).

Sustainable development (SD) consists of sustainability, SDGs, tourism, and crisis management. Environmental, social, and economic sustainability are the three pillars of SD, and these constructs must be integrated to produce a holistic approach. Environmental sustainability is concerned with limiting human activity to the carrying capacity of the ecosystem (materials, energy, land, and water, for example) that exists in a given area and places a premium on human life quality (air quality, human health). Additionally, economic sustainability takes into account the optimal use of resources to optimize operational profit and market value. Additionally, it addresses the substitution of natural for man-made resources, as well as reuse and recycling. However, social sustainability focuses on the populace's social well-being, balancing individual needs with communal needs (equity), public awareness and cohesion, and engagement and usage of indigenous labor and enterprises (Klymenko & Lillebrygfjeld Halse, 2021). The SDGs of the United Nations envision a peaceful future in which human existence flourishes in a secure, healthy, and sustainable environment devoid of disparities. However, in 2020, a global pandemic caused by COVID-19 occurred. In comparison to the pre-COVID-19 situation, this COVID-19 had a detrimental effect on human life, the economy, the environment, and the energy and transportation sectors. These sectors are interconnected, and hence the lockdown approach (G. D. Sharma, Talan & Jain, 2020) and stay-at-home policies implemented to prevent COVID-19 transmission had a profound influence on them (Aysan, Bergigui & Disli, 2021). The crisis management process entails much more than simply resolving the situation, although that is undoubtedly the most critical component. To fully grasp the intricacies of crisis management and organizational reaction, it can be beneficial to approach crisis management from a multi-level and interdisciplinary viewpoint, including individual, organizational, and institutional levels (Dubey, Bryde, Foropon, Tiwari & Gunasekaran, 2022). The connection between tourism and sustainable development can be viewed in a variety of ways, as demonstrated by the COVID-19 dilemma. Initially, a number of environmental benefits were identified, including significant reductions in pollution levels and greenhouse gas emissions as a result of the closure of numerous power plants and factories, the dramatic decline in air travel volume, and the restriction of people travelling by motor vehicle. However, such gains will almost certainly be reversed if/when the economy recovers (Janssen & van der Voort, 2020).

Healthcare comprises telemedicine, social responsibility, digital health, and social media. Healthcare systems face major challenges, especially during the COVID-19 pandemic, when the strongest developed economies, such as the USA, the UK, etc., were thrashed by the coronavirus. Healthcare 4.0 is a newly coined concept, taken from Industry 4.0. Healthcare 4.0 (Jayaraman, Forkan, Morshed, Haghighi & Kang, 2020) is a collective term for data-driven digital health technologies such as smart health, mHealth (mobile health), wireless health, eHealth, online health, medical IT, telehealth/telemedicine, digital medicine, health informatics, pervasive health, and health information systems. It is motivated by the fourth paradigm—data-intensive scientific discovery (Jayaraman et al., 2020). It discusses the digital frontiers and disruptive innovation now affecting the health care sector, which are resulting in the emergence of new business models and value networks. Healthcare 4.0 advancements and adoptions are unfolding in a number of industrialized countries worldwide, with the digital health market anticipated to reach $223.7 billion by 2023 (Herrmann et al., 2018). Health crises are more difficult to comprehend because they are often rare and unpredictable. Thus, health crises are comparable to black swans in that they occur unexpectedly but have catastrophic repercussions. Since December 2019, the magnitude of COVID-19′s impact on corporate organizations and the global economy has precipitated an unprecedented and unfathomable transformation in corporate social responsibility paradigms and practices as the globe tries to combat the coronavirus. Yet, long before COVID-19, the destabilizing effects of the Spanish flu, cholera, malaria, HIV-AIDS, environmental health crisis, H1N1, MES, E-bola, obesity, and the opioid epidemics, among others, on corporate stability catalyzed the gestation period of public-health-led CSR strategies aimed at pushing the boundaries of corporate social responsibility (Tworzydło et al., 2022). Social media has been imparting information to most of the people who access it. However, it has also been providing false information, especially during the COVID-19 crisis, which acted as another stressor for the general public. Chronic stress and disorientation during times of crisis can be exacerbated by repeated and extensive content about the virus, geographical statistics, and many sources of information. Added to this is the daily deluge of misinformation, rumor, and conspiracy theories. Boosted digitalization has increased media penetration, resulting in a larger number of people contributing to "information pollution" (Banerjee & Meena, 2021).

Sustainable economic performance consists of dynamic capabilities, innovation, economic performance, entrepreneurship, and corporate image. Dynamic capabilities and flexibility in response to a changing business environment are required for company strategy and organizational behavior. Dynamic capability is centered on interdependence with other businesses, so the role of resources becomes critical in helping small and medium-sized firms (SMEs) improve performance and maximize profits, while simultaneously raising income and welfare (Dovbischuk, 2022). At the moment, SMEs dominate the majority of the world's economies. As a result, they strive for technological superiority and continuous progress in their innovation operations. Surya et al. (2021) assert that facilitating business transformation, investment development, technological innovation, and management of SMEs will necessitate facilitating institutional reinforcement, modern business monitoring, and investment collaboration within a framework of controlling production factors and business opportunities. Concern for future generations' quality of life has prompted a more comprehensive vision and a more sustainable approach to company growth. Assessing an organization's performance, which should be multifaceted, through a single or consolidated lens would result in inaccuracies (Ch'ng, Cheah & Amran, 2021). According to scholarly works such as Evans et al. (2017) and Fernando, Chiappetta Jabbour and Wah (2019), three primary characteristics of sustainable company performance should be imputed: economic, social, and environmental value.

As a response to growing green consumerism and government laws, businesses are being compelled to include environmental considerations in their business strategies (Fernando et al., 2019). As consumer knowledge of environmental issues increases, businesses that portray a green image are better positioned to differentiate their products or services in the eyes of consumers. However, there are other strategies for establishing and enhancing a green corporate image (Fernando et al., 2019). Choudhury (2017) asserts that green-themed or "go green" marketing strategies might aid in establishing a firm's green image. Additionally, investing in environmental management provides them with power when dealing with non-profit organizations or governments, as well as an opportunity to improve their green image among customers (Fernando et al., 2019). Also, different studies (Awawdeh, Ananzeh, El-khateeb & Aljumah, 2022; Xie,

Huo & Zou, 2019; Ye & Cheng, 2019) have shown that businesses with a green entrepreneurial image not only increase sales volume, but also open up new markets, increase shopping value, and strengthen their competitive edge.

Reflections and directions for future research

Following the inductive analysis approach (Thomas & Tee, 2022), we propose a framework comprising first-order concepts, second-order themes, and aggregate dimensions. Our proposed framework comprises components such as technology adaptation, sustainable development, healthcare, and sustainable economic performance. These data structure components serve as the foundation for proposing emerging research hotspots in the field of COVID and innovation. They are derived from the commonalities identified during the analysis of the descriptive and conceptual structure of the existing literature (section 3), which are bolstered by the rigorous inductive analysis following Gioia's data structure recommendation (Kromidha, Gannon & Taheri, 2021) (see Fig. 4).

Technology adaptation

The COVID-19 pandemic has impacted practically every country, wreaking havoc on available healthcare facilities and treatment systems. There is a need for the adoption of numerous advanced technologies (such as AI, IoT, big data, etc.) in order to address the various issues associated with this viral epidemic. Industry 4.0, also known as the fourth industrial revolution, is a collection of advanced production and information technologies that enable human beings to meet the customized requirements of various regions in little time. These technologies enable wireless connectivity in manufacturing and service industries, hence increasing automation (Ahmad et al., 2022). In a fully implemented Industry 4.0 scenario, all of these technologies are connected, and medical stakeholders communicate with one another for vaccine manufacturing and use, healthcare equipment and logistics, check-up, surveillance, detection, and decision-making with minimal human physical involvement.

In the future, Industry 4.0 technology will be utilized to preserve sensitive health care system data that could be utilized in the event of another pandemic comparable to COVID-19. This revolution might be quickly accepted by professionals, doctors, and other staff members who have the ability to affect the treatment path for COVID-19 and other similar pandemics or epidemics (Ahmad et al., 2022). It is capable of centralizing all medical instruments, devices, and treatment processes. In the future, the medical industry will expand and will need to adapt to digital technologies in order to establish a smart healthcare system, necessitating the replacement of outdated software platforms and software equipment. This revolution enables disruptive innovation to mitigate the COVID-19 virus's influence (Ranjbari et al., 2021).

Adaptation to new technologies and novel financial applications is crucial for SME operations during a pandemic. This indicates that technologically integrated and financially viable SMEs are capable of operating in remote locations. Due to their cost-effective operations, they can remain untapped during a pandemic. An e-commerce application that incorporates M-banking provides the highest level of flexibility and efficiency for settling financial transactions without the need for a physical presence. SMEs on the route to e-commerce integration maintained an efficient supplier-customer connection during the lockdown state. Technology can assist SMEs in overcoming a variety of challenges they may face during COVID-19. Physical contact, demand forecasting, total sales and turnover improvement, market access, and profitability are all aided by several components of technology adoption. Until recently, businesses were unable to communicate with long-distance customers. The internet and other e-commerce resources, are currently revolutionizing and changing small and medium-sized businesses through the birth of the global concept of integration. Numerous traditional brick-and-mortar office buildings are obsolete as a result of the internet and e-commerce, which have created virtual technical offices for small and medium-sized firms. The owner should encourage personnel to leverage technology in order to increase financial and non-financial results. Employees will recognize the critical nature of technology adoption in order to deal with the current pandemic. Only technology can help a business continue operations in the event of a pandemic (Ranjbari, Morales-Alonso, Esfandabadi & Carrasco-Gallego, 2019).

Sustainable development

The COVID-19 problem has put an enormous strain on the global economy and corporate activity, causing huge financial losses, and increasing poverty and hunger (Singh & Singh, 2020). As a result, the pandemic's global health catastrophe delays the international community's progress towards sustainability (D. Lee, Kang & Kim, 2020). Barbier and Burgess (2020) suggested that COVID-19′s negative effects could jeopardize the UN's 2030 Agenda for Sustainable Development's 12 SDGs.

As per Filho, Brandli, Salvia, Rayman-Bacchus and Platje (2020), a reduction in the priority of the SDGs by COVID-19 also threatens sustainable development. While major global efforts are being made to contain the epidemic, post-COVID-19 sustainability should not be overlooked (Lambert et al., 2020). Sustainability and achieving the SDGs are now more important than ever. According to Elliott, Schumacher and Withagen (2020), rethinking sustainability should occur immediately, before the pandemic tragedy is over and people return to their usual lives, forgetting about future issues arising from the next pandemic. To assist governments, authorities, and sustainable development practitioners, researchers should produce a modified solid action plan that includes COVID-19 considerations.

To accomplish so, addressing the two elements below after COVID-19 is crucial. In order to identify the goals and targets based on the COVID-19 implication for any area of research, a thorough assessment of the COVID-19 implications on the 17 SDGs and their respective targets is required. The present SDGs of the UN 2030 Agenda for Sustainable Development require rethinking sustainability because they are not resilient enough to pandemic shock (Ibn-Mohammed et al., 2021). A measurement mechanism for COVID-19′s influence on progress towards sustainability pillars and sustainable development is also necessary (Dejardin et al., 2022). Because COVID-19 is so new, the lack of an acceptable and effective measurement tool for sustainability monitoring and assessment necessitates future research. According to Kanda and Kivimaa (2020), COVID-19 has provided a chance for the sustainability transition and rethinking sustainability to build a sustainable future.

We believe that now is the best time to encourage sustainable consumption and production patterns within sociotechnical regimes. Further research should focus on the sustainability opportunities presented by COVID-19 to SDG 12 (responsible consumption and production patterns), which ensures the sustainable use of natural resources. The potential of circular economy business models (Elliott et al., 2020), sharing economy platforms (Ranjbari et al., 2019), digitalization and digital sustainability (Pan and Zhang, 2020) as well as "glocalization" perspectives (Goffman, 2020) to increase community resilience and mitigate COVID-19 disruptive effects on sustainability is highly recommended. Moreover, post-COVID-19, the role of innovation and initiatives is critical. So, to fulfill SDG 9, we offer new insights into nurturing innovation processes and R&D units in the current world.

The tourism business has been severely hampered by global travel restrictions. During the COVID-19 crisis, official stay-at-home orders and partial lockdowns in numerous nations offered opportunities and threats to sustainable tourism. Higgins-Desbiolles (2020)

characterized the COVID-19 pandemic as a "game-changer" for the tourist sector and urged tourism academy members to promote and contribute to sustainable tourism in the aftermath of COVID-19 as scholars rather than competitors. Ryan, Coppola, Canyon, Brickhouse and Swienton (2020) presented a sustainability framework to ensure community stabilization by establishing baseline standards, regulations, and suggestions, as well as triggers and implementation. The authorities and decision-makers responsible for managing the COVID-19 situation must utilize a well-considered sustainable framework to combine lockdown and restrictive rules with societal requirements in order to handle the crisis more sustainably.

Healthcare

As previously stated, the COVID-19 pandemic is the most serious threat to world health in 2020, placing a significant strain on global healthcare systems. This strain puts healthcare systems' sustainability at risk and emphasizes the critical need for strategies and measures. According to Osingada and Porta (2020), in order to accomplish the SDGs following COVID-19, nursing actions and policies at the micro and macro levels of healthcare systems must be aligned with the 2030 Agenda for Sustainable Development. Additionally, healthcare system decision-makers must plan for a sustainable resume of elective surgeries, placing patient and surgical staff safety first during COVID-19, to cut costs and remain economically viable (O'Connor, Anoushiravani, DiCaprio, Healy & Iorio, 2020). Early detection of positive patients is critical to sustain the healthcare system's fight against the COVID-19 pandemic. Moreover, the use of smartphone-based healthcare monitoring technologies may help ensure the healthcare system's viability during the COVID-19 pandemic catastrophe.

Strategic planning and management are critical for controlling and preventing the COVID-19 pandemic and its negative consequences promptly. Authorities and policymakers must develop a well-defined strategic strategy for detecting confirmed cases, tracking indicators, sustaining healthcare systems, and successfully managing resources beyond the COVID-19 crisis, taking economic, social, and environmental factors into account. Furthermore, recent national and worldwide events have illustrated the impact of a large-scale healthcare emergency on current healthcare infrastructures and the difficulties that healthcare facilities have in surging to meet these demands. One strategy for addressing these difficulties is to harness existing telemedicine and other digital health technologies to expand health care competency and capacity at the local, regional, and national levels. Scott et al. (2020) emphasize the critical importance of establishing a flexible, scalable, robust, and, most importantly, interoperable National Emergency Tele-Critical Care Network (NETCCN) to ensure that the appropriate digital health ecosystem is available to respond to future disasters or emergencies. The ability and capacities obtained through continued NETCCN, both during and between crises, will enable increased care provision, distribution, and quick deployment at scale, thereby enhancing our nation's security.

Additionally, the current pandemic of COVID-19 is producing widespread psychosocial health problems in the general population, including stress, anguish, fear, anxiety, depressive symptoms, sleep disruptions, denial, rage, impatience, and mistrust (Mukhtar, 2020). These psychological difficulties affect medical personnel's concentration and decision-making capacities, posing a threat to the battle against COVID-19. Meyer et al. (2022) suggest that people may reveal that they are less susceptible to COVID-19, when amplifying their sense of self-efficacy, however, the stressor agents such as economic and social repercussions persist. Psychological difficulties account for between 4% to 41% of post-traumatic symptoms and 7% of depressive symptoms in the general population (Kang et al., 2020). The widespread dissemination of disinformation online about COVID-19 and the virus that causes it has greatly harmed the adoption of suggested preventative and control practices (Bridgman et al., 2020) and eroded support for critical, life-saving policies. Efforts by governments and health organizations, such as WHO (2020), to counteract online disinformation have generally focused on fact-checking, correcting, or debunking misconceptions and lies. While such reactionary behaviors are beneficial, social science research indicates that their impact is likely to be limited (Lewandowsky, Ecker, Seifert, Schwarz & Cook, 2012).

While fact-checking and corrections are critical components of the public health response to the COVID-19 misinformation epidemic, further efforts will be required to limit the misinformation's impact. Here, we provide several other techniques for consideration. Boosting the public's health and science literacy, for example, may greatly decrease susceptibility to misinformation: educating the public about the scientific research process may make people less likely to acknowledge spurious causal associations recommended by misinformation posts (MacFarlane, Hurlstone & Ecker, 2020); and educating the public about the iterative and advancing nature of scientific knowledge may make the public less impatient with the scientific process in the face of crisis. By utilizing their established relationships with patients, clinicians should also play a greater role in informing patients about COVID-19 disinformation. For example, rather than terminating the conversation when patients request an untested treatment based on information they found online, doctors could describe the significance of obtaining sufficient clinical evidence from rigorous studies, overview the possible risks of the treatment, and advise reliable sources of information to consult in the future.

Sustainable economic performance

COVID-19 has pushed the globe into the biggest economic recession since the Great Depression, resulting in the loss of 400 million jobs in the second quarter of 2020 and a 4.2 percent fall in GDP per capita in 2020 (Seth, 2015). Due to the severe economic consequences of this pandemic for society, there is an urgent need for new proposals to strengthen economic resilience and promote sustainable economic growth and decent work for all in line with SDG 8. Contributing to the advancement of an economic recovery strategy is critical in this regard, with a particular emphasis on the following research avenues: (1) investigating evidence-based economic analyses for long- and short-term recovery planning; (2) initiatives to strengthen the local economy following COVID-19; and (3) policy interventions to endorse small and medium-sized enterprises.

The problem of poor economic performance is exacerbated in emerging countries, particularly in less developed countries, which are more financially susceptible. The consequences of COVID-19 have had little impact on the attainment of SDG 8 and SDG 1 (no poverty). Prior to the pandemic, many countries formed a global partnership (SDG 17) to accomplish the UN's Sustainable Development Goals, and aid to least-developed countries and Africa increased by 2.6 percent and 1.3 percent, respectively, in 2019 (Seth, 2015). However, it is anticipated that the 554 billion dollars in remittances to low- and middle-income countries in 2019 will decline to 445 billion dollars in 2020, and worldwide foreign investment will decline by up to 40% in 2020 as a result of the pandemic (Seth, 2015). Therefore, while almost all countries are confronted with severe health and economic obstacles on their borders as a result of the pandemic, investigating practical solutions to support the partnerships specified in SDG 17 post-COVID-19 is strongly encouraged as the focus of future research to assist less-developed and developing countries in their transition to sustainable development.

Further, the literature demonstrates the importance of expanding research on innovation in the circular economy to all sectors, as many studies focus on the fashion and industrial sectors, with sectors concerned with the biological cycle receiving less attention. There is a need to approach new businesses and start-ups, as they may be

more efficient and successful at presenting radical innovations and uncovering specialized markets. Entrepreneurship is widely acknowledged as being critical to the development and well-being of society. They not only create riches through their business endeavors but also jobs and the circumstances necessary for a flourishing society. Ironically, the same entrepreneurial spirit is commonly blamed for the harmful consequences of its commercial activities on society. Researchers refer to such unsustainable corporate practices as a "business-as-usual model."

Interestingly, a green economy, in this conception, is a globally competitive economy that is also ecologically and socially sustainable. It establishes a genuine link between ecology and economics by enhancing social protection, combatting poverty, and promoting social justice. In light of recognized environmental limits, the objective is to achieve ecologically friendly, qualitative, and hence sustainable growth that is founded on a thorough understanding of the interrelationships between economics, finance, and politics. Sustainability is a way of managing resources in such a way that future generations' needs are not jeopardized (Purnomo, Adiguna, Widodo, Suyatna & Nusantoro, 2021). Green Entrepreneurship is a novel approach to attaining it, with the ultimate goal of developing diversified and sustainable production and consumption models that secure global prosperity and a high standard of living (Guan, Ahmad, Rahman & Halim, 2020).

There is also a need for research to be cross-pollinated between sustainable entrepreneurship (SE) and related fields. Apart from participation in worldwide comparative CSR studies and the literature on national business systems, there are additional topics that can inform SE studies. Increased contact with the social entrepreneurship literature, in particular, is a viable area for future research due to SE's environmental legacy. While SE research has shifted away from its environmental roots and toward a triple-bottom-line perspective, social entrepreneurship research, as its more recent brother, has the potential to inform SE in terms of evaluating and managing the social dimension of entrepreneurial activity (Emami et al., 2021). Similarly, cross-fertilization with the literature on social entrepreneurship might be advantageous, as the latter has gone into deeper detail about hybridity and hybrid tensions. Sustainable entrepreneurs are embedded in larger economic and social systems, interacting with a variety of other types of companies and societal stakeholder groups. As a result, the interaction with these other types of actors demands additional study. In this context, research on the varied roles and interactions of large and small organizations in the transition to more sustainable societies (Hockerts & Wüstenhagen, 2010) is critical. However, it will be necessary to investigate the longer-term dynamics of these interactions in order to fully grasp the numerous effects SE may have. To take one example, Holt (2012) examined a sample of pioneering ecopreneurs two decades after their inception and discovered that very few of them continue to operate in the same manner as they did in the beginning. Sustainable entrepreneurs may succeed or fail over time.

Conclusion

The COVID-19 outbreak has fostered the innovation dimension to mitigate the adversaries of the pandemic, and nations across the globe have embraced innovation as never before. The pandemic has naturally stimulated innovations in healthcare solutions and has catalyzed distance learning, remote working, e-commerce, and other mobility solutions. This paper has focused on innovation and innovation-driven policies during the time of COVID-19, based on an extensive literature review and bibliometric analysis.

During the unprecedented times of COVID-19, many frugal innovations have been set up. For instance, India refitted trains into hospital wards, and China constructed a hospital with a 1000-bed capacity (Harris, Bhatti, Buckley & Sharma, 2020). Most of the companies are channeled towards the production of face masks, sanitizers and ventilator machines. Investment in innovation resulting in scientific output, R &D expenditure, IP filings, and patent filings has increased during COVID-19. Scientific article publications have seen a growth of 7.6% along with government funding for R &D in medical technology, biotechnology, and pharmaceuticals (Soumitra et al., 2021). Increased innovation has been seen in software and ICT services, pharmaceuticals and biotechnology firms, while the travel and tourism sectors have cut down on their innovation outlays. Education and the healthcare system have created an environment for remote learning (Gopalakrishnan & Kovoor-Misra, 2021).

Digital tools were designed and implemented to cater to the need for research and innovation. The use of open data has helped in the promotion of the exchange of information and scientific advances related to health and hygiene. Many countries have also developed official websites for providing updated information about the spread of the virus and also to tackle misleading or false information (inaccurate and misinterpretation of scientific evidence) by the Federal Ministry of Education and Research in Germany. WHO launched a free health service alert for queries relating to COVID-19 on WhatsApp. Similarly, the 'MyGOV Corona helpdesk' in India has been launched to allow citizens to stay updated with the latest news and tally of COVID cases and monitor symptoms with further preventive measures.

One of the most favorable developments in STI pertains to vaccine development, which began during the SARS and MERS breakouts in 2003 and 2012, respectively, but newer technologies involved mRNA vaccines as compared to their predecessors, which mainly involve viral proteins or inactivated SARS-CoV-2 virus. The mRNA-based vaccines from Pfizer/BioNTech and Moderna have received their licenses and are quick to be manufactured and made available for combating the COVID-19 virus. There is a surge in public and private funding for the development of vaccines and facilitation of research and faster regulatory approvals are also seen in the trial phases of vaccine development (Chenevier, McCarthy & Joly, 2021; Ramalingam & Prabhu, 2020).

Another rush is seen in the number of research papers being published. However, quality checks remained a concern, but the publishing and presentation of research work took a virtual route during the pandemic. The use of scientific evidence is pertinent and visible in policy making, which reflects that policy-related documents have exclusive citations from published academic research articles. It is evident from the COVID-19 pandemic that scientific research reflects upon the socioeconomic aspects of policy decision-making.

Policy implications

Science, technology and innovation (STI) have the potential to play a bigger role in creating a more environmentally sustainable, inclusive, and resilient future. Greening ideas have been incorporated into recovery packages that have been put in place to help the economy recover. Previous STI policies that supported green and inclusive growth can provide important insights for developing recovery policies. STI can help develop strategies to better prepare for future crises such as pandemics, climate-related shocks, and cyberattacks. Shock agility and reactivity are two key aspects of resilience. COVID-19 could have an impact on several aspects of STI systems, as well as their resilience.

Following the extraordinary use of real-time granular data (e.g. movement data, pulse surveys) and big data visualization and analysis tools during the pandemic, new tools for STI policy may become more important. As a result, STI policy responses may become more flexible, targeted, and ultimately more effective. Unconventional policy methods, such as techniques that embed strategic foresight inside policymaking, i.e. the organized and explicit study of multiple futures to guide decision-making, could acquire traction in the coming years.

Systems methods, which take into consideration linkages in socio-economic activities, strive to develop policies that have an impact on the entire system rather than just one component or activity. When it comes to accelerating the shift to green mobility, for example, this necessitates investing in suitable technologies.

International patent fillings reflect that health-related technologies are being upgraded for recent inventions and the pandemic crisis has fueled the innovations due to support from many public-private funding agencies. Pharmaceuticals, biotechnology, medical technology, IT solutions for management, computer technology, digital communication, telemedicine, telecommunications, audiovisua technology, electrical machinery-apparatus, and energy are the major fields of innovation.

In times of crisis, a comprehensive approach to education that covers children's learning, social, and emotional needs is critical (Miller, 2020; Netz, Reinmoeller & Axelson, 2022). Due to school closures caused by the COVID-19 pandemic, kids from a variety of backgrounds are less likely to receive the support and extra resources they require, and the gap between pupils who face additional challenges and those who do not may deepen. Closures can also have a significant impact on students' emotions of belonging to schools and their self-worth, both of which are critical for inclusion in education. OECD member countries have looked forward to the re-opening of schools, and policymakers should ensure that COVID-19 transmission does not hinder students in the education system (OECD, 2020). Therefore, policymaking should be oriented towards ensuring and sustaining the vulnerable, leaving no one behind and investing in strategic government and private partnerships at local and national levels. With the prevalence of the COVID-19 pandemic, science, technology, and innovation (STI) provide implications for science, technology, and innovation policy. The impact of the COVID-19 crisis has raised a question about the pre-crisis condition and the role of STIs in government policies. Inclusion and sustainability, along with resilient STI policies, may prove to help prepare for any future crises (Acioli et al., 2021; Chenevier et al., 2021; Sampat & Shadlen, 2021).

COVID-19 has posed one of the greatest challenges faced by mankind, and its consequences have accelerated the public health crisis and mortality rate, with burgeoning issues at social, economic, and political levels. The major setbacks for innovation involve firstly, technical issues within innovation itself; secondly, business planning issues related to testing, implementation, and scaling-up; and lastly, institutional and political issues that remain at the status quo level and suppress novel solutions. The technologies in the areas of development and humanitarian work are regressed by the institutional environment and political power (Ramalingam & Prabhu, 2020). The domination by international authorities in emerging economies and vulnerable communities is also a major challenge for the innovation process to be unsuccessful. The innovation process is not seen as a strategic imperative but rather as a silo. Overall, the innovation process is risk-taking and involves high failure rates. However, humanitarian response and development can be achieved through trial-and-error by enabling learning and decision-making and balancing innovation risk appetite.

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Declaration of Competing Interest

None

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